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debarking chips from whole trees in the lake states

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DEBARKING CHIPS FROM WHOLE TREES IN THE LAKE STATES

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Field chipping of whole trees, coupled with an effective system for removing the bark from the chip mass, is a means of increasing the utilization of our forest resources.[1] By chipping in the field, the tops and limbs currently left in the forest can be recovered, and stands that are marginal or submarginal with present harvesting systems can possibly be harvested economically. A system that could effectively remove the bark from the chip mass would make whole-tree chips suitable for most paper-making processes and ensure an adequate market.

Several years of research at the Forest Engineering Laboratory (FEL) has shown that a process that will remove the bark from a chip mass is technically feasible.[2] The heart of the bark-chip separation-segregation (BCSS) system developed at the FEL is a compression debarker (fig. 1) that basically consists of two compression rolls that are hydraulically loaded to maintain the small "nip" spacing as chips pass between the rolls. Pressure separates the bark from the wood. The wood chips pass straight through the nip while the bark adheres to the rolls and is collected separately. Compression debarking alone can remove 50 to 70 percent of the bark in a chip mass.

Steaming the chips before compression removes significantly more bark. Steaming apparently softens the cambial layer of the bark and makes the bark tacky so that it adheres better to the compression-debarker rolls. Steaming before compression can increase total bark removal as much as an additional 30 percent of input bark.

The bark left in the chip mass after presteaming and compression debarking is concentrated in the small size fractions of the output. Earlier work has shown that mechanical attrition is feasible for reducing residual bark even further.[3] To obtain a final output that is practically bark free, a combination of presteaming, compression debarking, attrition, and removal of the smallest material (both bark and wood) from the output should be used. (The FEL has used 3 percent or less residual bark as the objective of the bark removal research, as recommended by the American Pulpwood Association.)

Mostly bolewood has been used in developing the BCSS system. This choice was made to reduce the number of variables in the test program and to simplify material acquisition and handling. However, before the BCSS system could be considered a solution to the problem of bark removal after chipping, it had to be demonstrated that BCSS could achieve acceptable results with whole-tree chips in all seasons of the year.

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[1] *John R. Erickson. Bark-chip segregation: a key to whole-tree utilization. For. Prod. J. 21(9):111-113. 1971.*

[2] *Rodger A. Arola and John R. Erickson. Compression debarking of wood chips. USDA For. Serv. Res. Pap. NC-85, 11 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn. 1973.*

[3] *James A. Mattson. Beneficiation of compression debarked wood chips. USDA For. Serv. Res. Note NC-180, 4 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn. 1974.*

SR-SMOOTH STEEL ROLL
KR-KNURLED STEEL ROLL

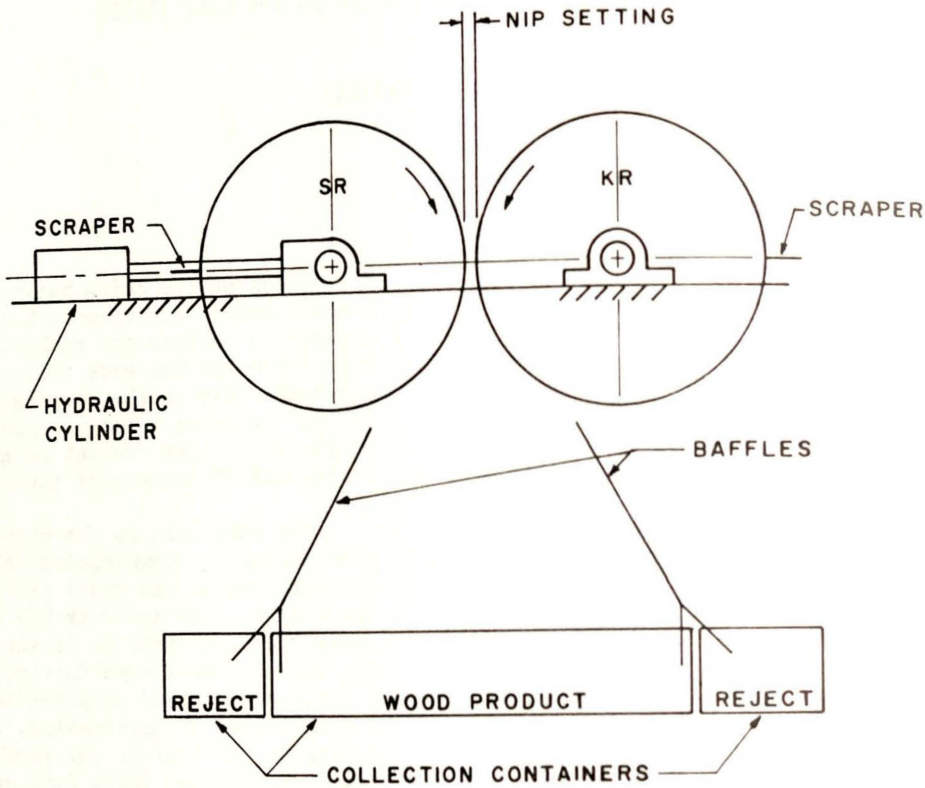

Figure 1.--*Simplified schematic diagram of the compression debarker.*

OBJECTIVES

The objective of this study was to evaluate, in terms of bark removal and wood recovery, the effectiveness of the compression debarker plus the complementary presteaming and attrition treatments on whole-tree chips of three major Lake States species, quaking aspen (*Populus tremuloides* Michx), sugar maple (*Acer saccharum* Marsh), and jack pine (*Pinus banksiana* Lamb).

SAMPLE MATERIAL

Three sample trees of each species were cut bimonthly from March 1973 to January 1974. All the trees were obtained from the lands of the Ford Forestry Center of Michigan Technological University near L'Anse, Michigan. The trees were chipped with a Morbark Chip-pac[4] owned and operated by the Ford Forestry Center. The chipper was equipped with an oversize screen and has rechipping capability so oversized chips were eliminated. The chipper has a 9-inch spout so the trees sampled in this study were all in the 6-to 8-inch diameter class (table 1).

[4] *Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

Table 1.--*Data on trees chipped*[1]

Date cut and chipped	D.b.h.	Height	Age	Total green weight of chips	Moisture content[2]		Specific gravity[3]	
					Wood	Bark	Wood	Bark
	Inches	*Feet*	*Years*	*Lbs*	*Percent*	*Percent*		
ASPEN								
3-13-73	7.0	66.3	75.0	464	100.9	77.2	0.376	0.539
5-16-73	6.9	67.1	73.7	497	106.1	77.0	.378	.544
8-3-73	7.0	68.6	74.0	522	98.5	100.4	.366	.472
9-26-73	6.9	64.0	76.7	456	88.4	97.5	.374	.499
11-28-73	7.0	68.7	69.7	533	103.5	86.9	.368	.526
1-18-74	7.2	67.6	70.3	608	121.4	89.8	.349	.500
Mean	7.0	67.0	73.2	513	103.1	88.1	.368	.513
SUGAR MAPLE								
3-22-73	6.9	49.6	71.3	495	63.6	55.3	0.601	0.605
5-23-73	6.8	50.9	61.0	419	58.6	67.2	.598	.536
7-23-73	6.9	52.0	74.3	432	58.3	89.1	.545	.459
9-27-73	6.6	57.4	71.7	445	56.4	81.6	.581	.468
11-20-73	7.0	58.4	71.0	519	64.8	64.4	.584	.512
1-23-74	6.8	56.1	65.0	463	69.4	55.4	.558	.566
Mean	6.8	54.1	69.1	462	61.9	68.8	.578	.524
JACK PINE								
3-23-73	7.1	53.0	42.3	449	103.5	158.2	0.368	0.295
5-9-73	6.8	50.5	40.7	425	121.1	150.0	.367	.314
7-11-73	7.2	54.5	43.3	456	127.9	207.0	.350	.256
9-14-73	6.9	53.6	45.0	447	108.4	208.9	.361	.285
11-29-73	6.9	54.1	45.7	449	103.2	167.2	.374	.338
1-25-74	7.6	51.8	44.0	508	100.6	163.5	.361	.294
Mean	7.1	52.9	43.5	456	110.8	175.8	.363	.297

[1]Mean values for three trees.
[2]Oven-dry.
[3]Dry weight/green volume.

After chipping, the material from each tree was thoroughly mixed and a 100-pound sample taken for analysis. The 100-pound sample was screened into several size classes (1-1/8 inch, 5/8 inch, 3/8 inch, 3/16 inch, and fines), and smaller samples were taken of each size class to obtain bark and foliage contents. Additional samples were taken to determine moisture contents and specific gravities of the wood and bark.

The season in which the trees are cut has a significant effect on the amount of bark-wood (wood chips with bark still attached) present in the chips. The bark-wood in the sample chips ranged from 2 to 20 percent of the total chip mass depending on the season (table 2). The added requirements of breaking the bark-wood bond before segregating the bark from the wood reduces the amount of bark that can be removed by one pass through the compression debarker.

Most chips are in the 5/8-inch and 3/8-inch size fraction (table 3). These two size fractions contain over 70 percent of the total material and about 80 percent of the total wood present in the chip mass. The smaller chips contain a greater proportion of the bark than the larger chips, but the bark percents in all size fractions is too high to selective screen chips to obtain a product with an acceptable level of bark.

Table 2.--*Chip analysis of whole-tree chips by cutting date*[1]
(In percent)

Cutting date	Free wood	Free bark	Bark-wood	Bark-wood: Wood	Bark-wood: Bark	Total wood	Total bark	Twigs	Foliage
ASPEN									
3-73	65.27	13.84	20.30	50.08	41.92	77.07	22.34	0.59	0
5-73	72.58	20.42	5.92	54.72	45.28	75.88	23.03	1.08	0
7-73	71.73	18.72	6.99	61.94	38.06	76.04	21.42	1.11	1.44
9-73	66.23	16.17	15.08	59.24	40.76	75.23	22.26	1.27	1.25
11-73	69.95	15.08	14.29	57.26	42.74	78.11	21.21	.68	0
1-74	73.69	17.98	7.91	53.10	46.90	77.90	21.68	.43	0
SUGAR MAPLE									
3-73	77.95	11.39	9.05	82.92	17.08	85.45	12.93	1.62	0
5-73	81.42	13.98	2.90	79.35	20.65	83.73	14.57	1.69	0
7-73	78.77	13.36	2.14	79.21	20.79	80.46	13.81	1.96	3.78
9-73	72.28	11.53	11.52	80.66	19.34	81.62	13.72	2.65	2.02
11-73	77.26	10.42	10.54	79.48	20.52	85.63	12.59	1.78	0
1-74	77.58	11.33	9.48	82.80	17.20	85.43	12.96	1.61	0
JACK PINE									
3-73	68.88	5.95	18.12	82.27	17.73	83.73	9.19	2.06	4.98
5-73	72.13	11.06	4.92	76.89	23.11	75.93	12.18	3.97	7.93
7-73	75.62	11.57	3.88	80.14	19.86	78.83	12.34	2.94	5.99
9-73	69.08	8.73	12.09	83.67	16.33	79.21	10.69	3.32	6.77
11-73	67.38	6.96	16.02	79.72	20.28	80.16	10.20	3.23	6.41
1-74	77.15	7.09	9.47	74.71	25.29	84.23	9.49	2.33	3.95

[1]Mean values for three trees.

Table 3.--*Chip analysis of whole-tree chips by size fractions*[1]
(In percent)

Chip size (inches)	Total chips	Wood	Bark	Twigs	Foliage	Total wood in run	Total bark in run
1-1/8	9.41	81.50	15.64	2.16	0.70	10.10	6.38
5/8	55.23	87.22	11.71	.72	.35	62.81	29.41
3/8	25.33	65.05	33.77	.85	.33	21.58	38.49
3/16	6.98	45.90	52.56	.81	.73	4.23	16.51
Fines	3.05	31.23	67.22	0	1.54	1.28	9.21
Total	100	76.70	21.99	.86	.45	100	100
SUGAR MAPLE							
1-1/8	17.22	93.20	2.80	3.45	0.56	19.33	3.52
5/8	51.77	93.10	4.88	1.23	.79	57.56	18.67
3/8	21.21	73.65	23.17	2.20	.98	18.80	35.56
3/16	6.86	42.38	51.37	3.67	2.58	3.50	26.20
Fines	2.93	21.64	74.24	.05	4.07	.81	16.05
Total	100	83.72	13.43	1.89	.97	100	100
JACK PINE							
1-1/8	10.82	86.06	5.26	4.77	3.91	11.72	5.41
5/8	48.29	89.29	5.39	1.55	3.81	53.62	24.28
3/8	25.37	83.93	10.03	3.92	2.12	26.55	23.36
3/16	10.12	53.25	22.71	7.84	16.20	6.79	21.68
Fines	5.40	18.34	51.15	0	30.51	1.31	25.27
Total	100	80.36	10.68	2.97	6.01	100	100

[1]Mean values for 18 trees.

TEST PROCEDURE

Four 50-pound batches of chips were taken from each tree. Each batch was processed for bark removal by a different treatment as follows:

1. Compression debarked only (hereafter referred to as process "C"). (For all compression debarker runs, the machine variables were set at previously determined optimum values: 0.020-inch nip spacing, 1,400 pounds/lineal inch hydraulic pressure on the rolls, 640 surface feet/minute roll speed, and 1 ft^3/minute feed rate.)
2. Presteamed at 10 $lb/in.^2$ for 5 minutes and compression debarked. (Process "S10C".)
3. Presteamed at 30 $lb/in.^2$ for 5 minutes and compression debarked. (Process "S30C".)
4. Process S30C followed by a hammermilling of the two smaller size fractions of the compression debarker output (those chips that passed a 5/8-inch screen but were retained on a 3/16-inch screen). The hammermill used in this study was a modified laboratory coal crusher equipped with a bar screen with the bars running perpendicular to the axis of the hammer shaft (fig. 2). Three solid full-length hammers were used in the mill. (The hammermill was used on the last four cuttings only.)

Each run was analyzed for size classes, percent of wood, bark, and foliage by size classes, percent of input bark and foliage removed, and percent of input wood recovered. All analysis was done on an oven-dry basis.

RESULTS

The tests show that bark removal for process S30C is significantly better than both process S10C and process C for all three species during all cutting seasons (fig. 3). Process S30C removes an average of 12.5 percent more bark than process S10C and an average of 33.3 percent more bark than process C.

Wood recovery for aspen is not significantly different for the three processes or cutting seasons, but both maple and jack pine wood recovery are affected by both process and cutting season. Wood recovery for jack pine and maple is significantly lower for process S30C than for the other processes; maple wood recovery is lower during the foliage season and jack pine wood recovery is significantly lower during the dormant season. A significant portion of the wood lost during steaming and compression debarking adheres to the knurled roll of the compression debarker. The use of the two smooth rolls on the compression debarker is being investigated as one means of reducing this loss. A separate study has also indicated that about 70 percent of the wood fiber that is removed by the knurled roll can be easily recovered.[5]

The presteaming-compression debarking process is effective in removing foliage from whole-tree chips of jack pine only; an average of 58 percent of the input foliage. Similar to the residual bark, the residual foliage is concentrated in the small size fractions of the output from the compression debarker.

The total mean residual bark content of the presteamed and compression debarked chips (process S30C) ranges from 3.36 percent to 5.30 percent for aspen, 4.22 percent to 7.35 percent for maple, and 3.19 percent to 4.54 percent for jack pine (table 4). Thus, the presteaming and compression debarking process alone does not reduce the residual bark content to the desired level of 3 percent or less. For all species and cutting seasons, the residual bark content of the 1-1/8-inch and 5/8-inch size classes are less than 3 percent, but both the 3/8-inch and 3/16-inch size classes exceed the desired bark content for all species because the bark is concentrated in these fractions (table 5).

Hammermilling the chips smaller than 5/8-inch from the compression debarker output further reduces the size of the bark particles and concentrates the residual bark in the 3/16-inch size fraction. Removal of this size fraction then reduces the output to less than 3 percent bark for all conditions (table 6). The addition of the hammermilling and eliminating the 3/16-inch size fraction also reduces the wood recovery to a range of 71 to 88 percent. However, the particles removed are of uniform size and should be ideally suited for use either in particleboard or as boiler fuel.

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[5] *Rodger A. Arola. Fiber recovery from compression debarking roll waste. (In process.)*

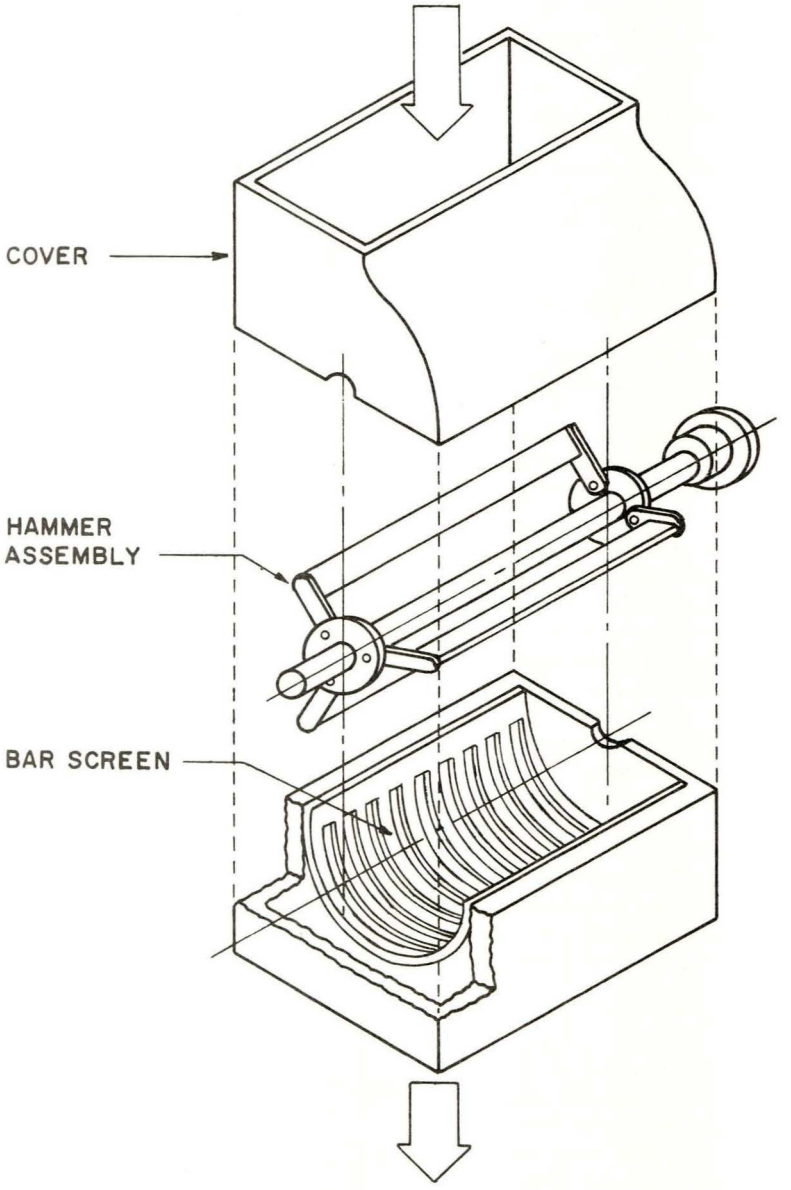

Figure 2.--*Schematic of hammermill used to beneficiate output of compression debarker.*

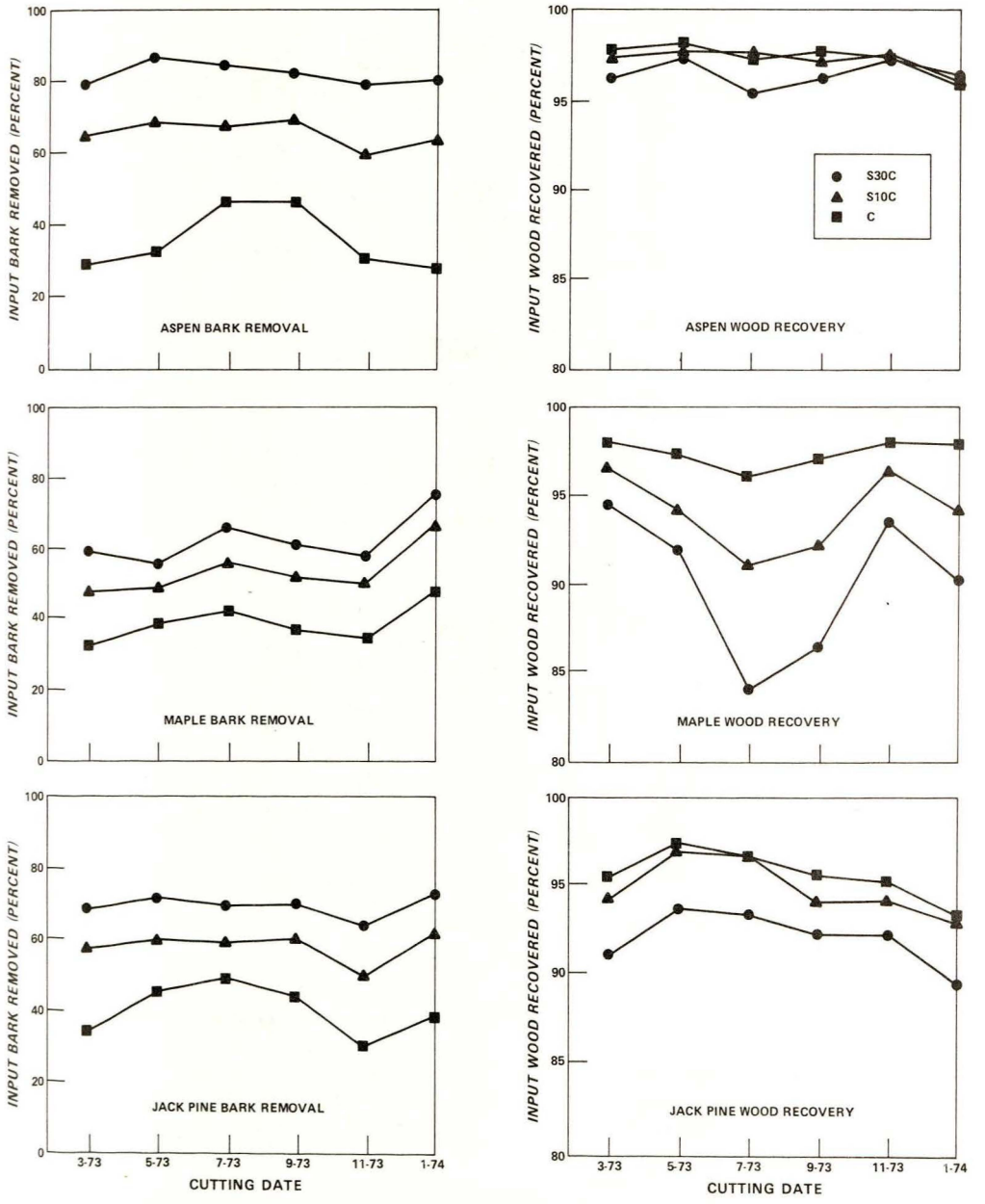

Figure 3.--*Bark removal and wood recovery for aspen, sugar maple, and jack pine for processes S30C, S10C, and C by cutting date.*

Table 4.--*Compression debarking*[1] *results for whole-tree chips*
(In percent)

Cutting date	Input bark	Output bark	Input bark removed	Input Foliage	Output Foliage	Input foliage removed	Total weight removed	Input wood recovered
				ASPEN				
3-73	19.34[2]	4.82	79.67	--	--	--	18.44	96.24
	(0.67)	(0.25)	(0.54)				(0.94)	(0.81)
5-73	21.18	3.36	87.43	--	--	--	20.53	97.43
	(1.38)	(0.54)	(1.12)				(0.91)	(0.25)
7-73	20.14	3.97	84.38	0.96	0.86	28.11	20.82	95.48
	(0.79)	(0.24)	(0.20)	(0.31)	(0.28)	(6.10)	(1.17)	(0.66)
9-73	21.42	4.75	82.34	1.05	1.05	21.32	20.75	96.27
	(0.73)	(0.45)	(2.40)	(0.37)	(0.42)	(3.75)	(0.96)	(0.15)
11-73	19.98	4.93	79.72	--	--	--	18.13	97.33
	(0.36)	(1.20)	(5.51)				(1.73)	(0.61)
1-74	21.54	5.30	80.35	--	--	--	20.22	96.29
	(0.38)	(0.92)	(3.43)				(1.10)	(0.93)
				SUGAR MAPLE				
3-73	12.81[2]	5.87	59.90	--	--	--	12.37	94.62
	(1.01)	(0.82)	(3.83)				(2.35)	(3.11)
5-73	14.24	7.35	56.09	--	--	--	14.86	91.99
	(0.14)	(0.34)	(2.86)				(3.65)	(3.85)
7-73	14.33	6.45	66.10	1.85	1.58	31.92	23.15	83.93
	(1.27)	(2.06)	(6.89)	(0.58)	(0.69)	(10.45)	(4.31)	(5.29)
9-73	14.25	6.90	61.56	1.79	2.03	18.72	20.65	86.50
	(1.51)	(0.79)	(2.56)	(0.84)	(1.04)	(4.27)	(3.22)	(3.69)
11-73	14.01	6.80	58.16	--	--	--	13.64	93.59
	(0.70)	(1.19)	(6.45)				(2.54)	(2.26)
1-74	14.10	4.22	75.80	--	--	--	19.10	90.22
	(0.43)	(0.21)	(0.93)				(3.40)	(4.40)
				JACK PINE				
3-73	8.63[2]	3.19	68.69	3.34	1.80	54.24	15.58	91.11
	(0.76)	(0.20)	(1.80)	(0.95)	(0.48)	(2.56)	(1.70)	(1.10)
5-73	12.48	4.30	71.47	4.84	2.48	57.73	16.91	93.69
	(0.76)	(0.50)	(1.60)	(0.38)	(0.56)	(7.07)	(0.56)	(0.56)
7-73	10.33	3.74	69.34	3.53	1.44	65.12	15.12	93.42
	(0.62)	(0.37)	(0.94)	(0.57)	(0.23)	(2.64)	(2.56)	(2.41)
9-73	11.24	4.06	69.76	3.99	2.14	55.29	16.63	92.26
	(1.17)	(0.30)	(2.45)	(0.64)	(0.32)	(4.47)	(1.72)	(1.36)
11-73	10.29	4.54	62.66	4.82	2.36	59.09	16.60	92.13
	(1.37)	(0.29)	(3.45)	(0.75)	(0.44)	(1.75)	(0.48)	(0.88)
1-74	9.99	3.52	71.44	3.07	1.56	58.70	18.05	89.49
	(1.12)	(0.83)	(3.53)	(0.91)	(0.49)	(2.18)	(0.53)	(0.53)

[1]Process S30C.
[2]Mean with standard deviation in parenthesis.

CONCLUSIONS

Presteaming followed by compression debarking can remove 55 to 90 percent of the input bark in a mass of whole-tree chips of three major Lake States species, quaking aspen, sugar maple, and jack pine. Residual bark contents range from 3.2 percent to 7.5 percent and wood recovery from 80 to 97 percent.

Addition of a hammermill treatment on the size fraction smaller than 5/8-inch after compression debarking and elimination of the bark-heavy 3/16-inch size fraction reduces the residual bark content to 3 percent or less for all three species. Thus, whole-tree chips processed by the BCSS system of the Forest Engineering Laboratory are suitable for use in all but the most stringent pulping operations.

It is true that more wood is lost in BCSS than in conventional roundwood debarking systems. However, the increased amount of fiber recovered per acre when whole-trees are harvested will mean more clean chips available for pulping. In addition, the reject material from the BCSS can easily be used in a secondary product or as fuel.

Table 5.--*Output, bark, and foliage remaining in chips of various sizes after presteaming and compression debarking whole-tree chips*
(In percent)

Cutting date	1-1/8 inch			5/8 inch			3/8 inch			3/16 inch		
	Output	Bark	Foliage	Output	Bark	Foliage	Output	Bark	Foliage	Output	Bark	Foliage
ASPEN												
3-73	7.55	0.54	0	61.82	0.71	0	24.09	7.67	0	6.54	38.35	0
5-73	6.80	.38	0	63.18	.21	0	23.87	5.58	0	6.15	30.39	0
7-73	9.96	.11	1.18	63.40	.85	0.72	20.93	7.38	0.63	5.71	33.37	2.93
9-73	8.33	.48	1.18	62.35	.93	.70	22.46	7.19	1.56	6.86	37.13	2.47
11-73	5.33	.26	0	60.55	.82	0	27.25	7.62	0	6.88	33.54	0
1-74	4.72	.39	0	59.37	.93	0	27.85	8.21	0	8.06	30.15	0
SUGAR MAPLE												
3-73	9.89	0.41	0	58.61	0.62	0	23.18	6.76	0	8.33	47.09	0
5-73	13.45	.50	0	56.22	.96	0	22.41	12.85	0	7.92	48.52	0
7-73	12.48	.47	0.50	59.24	1.55	1.43	20.97	12.10	3.35	7.30	39.96	6.28
9-73	17.42	.94	.53	50.82	1.03	1.12	22.60	10.97	1.93	9.15	40.82	5.27
11-73	12.25	.59	0	55.83	.94	0	23.61	10.09	0	8.30	46.02	0
1-74	8.43	.72	0	55.23	.57	0	27.38	4.29	0	8.96	33.10	0
JACK PINE												
3-73	6.04	0.67	0.09	49.89	0.45	0.20	34.26	3.21	1.06	9.81	18.87	13.49
5-73	6.02	1.09	0	50.55	.71	0	32.68	4.29	0.95	10.75	23.09	20.16
7-73	7.55	.62	.05	50.83	.84	0	31.72	4.42	.48	9.90	19.11	13.23
9-73	6.17	.80	.12	50.94	.58	0	31.89	4.31	.71	10.99	21.34	17.40
11-73	4.88	1.01	.16	52.85	1.17	.10	31.40	5.66	.95	10.87	19.42	18.33
1-74	3.23	1.19	.13	44.58	.78	0	37.95	2.61	.92	14.24	14.84	8.35

[1]Process S30C.

Table 6.--*Compression debarking*[1] *results with minus 5/8-inch fraction hammer-milled and minus 3/8-inch fraction discarded from output*
(In percent)

Cutting date	Input bark	Output bark	Input bark removed	Input Foliage	Output Foliage	Input foliage removed	Total weight removed	Input wood recovered
ASPEN								
7-73	19.03[2]	1.26	95.26	1.12	0.89	43.92	28.38	87.78
	(0.79)	(0.22)	(0.94)	(0.12)	(0.20)	(8.46)	(0.69)	(0.52)
9-73	21.59	1.65	94.67	1.09	0.95	38.77	30.33	87.76
	(1.02)	(0.06)	(0.55)	(0.19)	(0.12)	(9.79)	(1.92)	(1.90)
11-73	20.14	1.79	93.60	--	--	--	28.17	88.35
	(0.19)	(0.31)	(1.15)				(0.34)	(0.38)
1-74	21.42	1.71	94.41	--	--	--	30.58	86.83
	(0.88)	(0.83)	(2.79)				(1.44)	(1.95)
SUGAR MAPLE								
7-73	14.17	1.99	90.68	1.87	1.49	47.06	33.39	76.57
	(0.50)	(0.77)	(3.43)	(0.96)	(0.84)	(7.92)	(1.16)	(1.40)
9-73	15.02	2.34	89.52	1.44	0.97	59.06	33.70	76.73
	(1.05)	(0.55)	(3.45)	(0.51)	(0.63)	(11.41)	(3.75)	(3.86)
11-73	13.56	1.60	91.32	--	--	--	24.95	85.45
	(1.09)	(1.23)	(6.28)				(2.55)	(3.03)
1-74	14.15	1.16	94.43	--	--	--	31.32	79.07
	(1.05)	(0.21)	(0.40)				(3.67)	(3.81)
JACK PINE								
7-73	10.27	1.40	90.45	3.75	0.22	95.84	28.99	81.27
	(0.56)	(0.52)	(3.14)	(0.39)	(0.08)	(1.57)	(2.04)	(2.75)
9-73	10.76	1.03	93.66	3.95	0.21	96.29	32.43	78.28
	(1.09)	(0.48)	(2.53)	(0.68)	(0.09)	(1.61)	(2.50)	(3.58)
11-73	10.79	2.12	86.53	4.74	0.51	92.53	31.75	78.66
	(0.88)	(0.10)	(1.60)	(0.11)	(0.22)	(3.55)	(3.16)	(3.20)
1-74	11.65	1.83	89.01	3.77	0.34	94.75	38.52	70.92
	(3.30)	(0.49)	(5.79)	(1.30)	(0.19)	(1.21)	(7.56)	(5.01)

[1]Process S30C.
[2]Mean with standard deviation in parenthesis.

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